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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VI PHENOLIC RESIN LINING

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *May* 1971

Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VI PHENOLIC RESIN LINING

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART VI PHENOLIC RESIN LINING

0. FOREWORD

0.1 This Indian Standard (Part VI) was adopted by the Indian Standards Institution on 23 December 1970, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard is being issued in many parts; the phenolic resin linings of vessels and equipment is covered in this part, the other types of linings are covered in the remaining parts of this standard.

0.3 The use of linings of polymeric materials as a protection against corrosion has been the normal industrial practice for nearly half a century. A bond is developed between the applied lining and the metal and any attempt to pull them apart will normally result in the lining tearing before the bond yields. Thus the lined vessels are quite suitable for use either under vacuum conditions or under pressure conditions. While it is normal to use lined metallic vessels, non-metallic surfaces like wood and concrete are also often lined.

0.4 Phenolic linings are based on resins usually formed by the reaction of phenol and formaldehyde or its modifications. They are usually applied as a formulation containing solvents, pigments, filters, etc, to get the desired properties, curing of the lining being effected by stoving at an elevated temperature. It is possible to cure these linings at ambient temperatures by the use of acid catalysts, but this procedure has not given satisfactory results in practice.

0.5 The selection of the lining and its method of application is to be based on the information supplied by the user. Therefore, it is necessary that full details and duties are submitted to the contractor to enable him to choose the suitable lining. Appendix A gives the information to be exchanged between contractor and user.

0.6 While in the preparation of this standard, assistance has been dervied from BS CP 3003 : Part 6 : 1966 ' Lining of vessels and equipment for chemical processes, Part 6 Phenolic resin ', issued by the British Standard Institution.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part VI) lays down recommendations for lining of vessels and equipment provided with a phenolic resin based lining applied as a thin coating and stoved.

2. TERMINOLOY

2.0 For the purpose of this standard, the following definition shall apply.

2.1 Phenolic Resin Linings — Linings based on resins usually formed by the reaction of a phenol and formaldehyde and the modifications thereof.

3. MATERIALS

3.1 Purpose

3.1.1 Phenolic resin linings are used for protecting equipment against chemical attack. They are also used for the prevention of contamination of various products by minute quantities of impurities which might be formed by direct contact with metallic equipment.

3.1.2 These linings can also be used to prevent the deposition of solids on the walls of the equipment and to facilitate cleaning.

3.1.3 Unless the lining is known from previous experience to be suitable, test panels should be exposed to conditions similar to those of service for not less than three months or preferably longer. The panels should be examined carefully for any signs of failure before intructions for application of the linings are given.

3.2 Properties

3.2.1 Phenolic resin linings are normally applied as single pack solvent solutions which may contain pigments and fillers. They are stoved at elevated temperatures to remove solvents and cure the resin. The stoving temperatures are specified by the supplier and these will normally be in the range of 150 to 180°C. Heating during *in situ* is possible, but presupposes adequate insulation of the vessel and careful temperature control is necessary.

*Rules for rounding off numerical values (*revised*).

3.2.2 The chemical resistance of these coatings is dealt with in **3.2.2.1** to **3.2.2.9**. It should be noted that where pigments or fillers are used, they should be resistant to any corrosive substance likely to be encountered. In all cases it is assumed that a sufficiently thick and pin-hole-free lining has been applied.

3.2.2.1 *Resistance to acids* — These linings resist most acids except those of a strongly oxidizing nature. Nevertheless, possible imperfections in the lining caused by the application difficulties or mechanical damage render them unsuitable if rapid attack of the base material would occur through direct contact with the acids.

3.2.2.2 *Resistance to alkalis* — These linings are resistant only to mild alkaline solutions (*p*H value not above 10). Consequently, care shall be taken to select only mildly alkaline detergents for cleaning purposes.

3.2.2.3 *Resistance to salts* — They are generally resistant to neutral salts, but salts giving strongly alkaline solutions should be avoided.

3.2.2.4 *Resistance to chlorine and hypochlorites* — Apart from limited resistance to dry chlorine these linings are unsuitable for use with wet chlorine or solutions of hypochlorites.

3.2.2.5 *Resistance to solvents* — They are resistant to a very wide range of solvents.

3.2.2.6 *Effect of temperature* — In general, these linings may be used at temperatures up to about 150°C for dry conditions and about 80°C for wet conditions. For short periods this maximum temperature of 80°C for wet conditions may be exceeded, for example, for steam sterilization and cleaning.

3.2.2.7 *Effect on heat-transfer rates* — The effect of these linings on heat-transfer rates is negligible.

3.2.2.8 *Resistance to erosion* — These linings are hard, tough and glossy, and offer good resistance to erosion by suspended particles.

3.2.2.9 *Resistance to surface deposit formation* — They have good resistance to the build up of deposits.

4. DESIGN OF VESSELS AND EQUIPMENT

4.1 General

4.1.1 *Interior Surfaces and Fittings* — The surfaces which are to be covered with phenolic resins shall be easily accessible and free from pitting or other physical imperfections. Interior fittings should be designed to allow safe and easy movement of the operator or, if this is not possible, a manhole should be provided in each section of the vessel being lined.

4.1.2 *Access to Vessel and Ventilation* — The design of all vessels and equipment shall allow for adequate access and venting of fumes evolved during the preparation of the surface and the application of the coating.

4.1.2.1 In completely enclosed vessels, there shall be at least one manhole conforming to IS : 3133-1965* and one additional branch of not less than 75 mm bore. The method of ventilation shall be the subject of agreement at the tendering stage between the lining contractor and the customer and shall ensure that in no case can pockets of stagant vapour or gas occur.

4.1.3 The allowances should be made for the thickness of the lining or covering in calculating clearances.

4.1.4 *Branches and Outlets* — All branches and outlays shall be flanged and the lining taken over the flange face to prevent the ingress of liquors behind the linings.

4.1.5 *Surface Contours* — Sharp changes of contour in the surface to be covered shall be avoided wherever possible and such changes shall be finished to suitable radius; in all cases this shall be such that the internal radius of the lining is not less than 4 mm or the thickness of the lining (*see* Fig. 1).

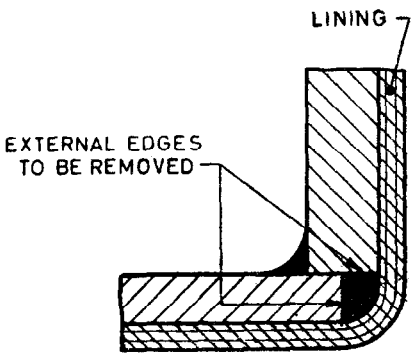

FIG. 1 ROUNDING OF EXTERNAL ANGLES

4.1.6 *Heating* — Any steam coil of immersion heater used for heating the contents of the vessel shall be situated not less than 100 mm away from the phenolic resin lined surface to avoid local overheating. When heating by steam injection, care shall be taken to avoid direct impingement of steam on the phenolic resin surface.

4.2 Fabricated Mild Steel Vessels

4.2.1 *Fabrication and Testing* — Mild steel vessels should be fabricated and tested in accordance with recognized standards of good design and practice. Only welded or seamless construction shall be used. Riveted constructions shall not be used.

*Specification for manhole and inspection openings for chemical equipment.

4.2.2 *Vessels to be Provided with Stoved Linings* — Special precautions are necessary for fabricated mild steel vessels which are to be provided with phenolic resin linings, so as to prevent the occurrence of lining failures during stoving. For this reason, the recommendations in **4.2.2.1** and **4.2.2.2** should be followed.

4.2.2.1 *Welded joints* — Welding shall be in accordance with the requirements of either IS : 823-1964*, IS : 1323-1966†, or IS : 2825-1969‡. Lap joints should be avoided as far as possible. Butt-welds in both butt joints and T joints, shall be made with more than one run of the electrode or blowpipe. The weld shall be ground smooth and flush on the side to be covered. Welds shall be made from the side to be covered wherever possible. Where it is not possible to weld from the side to be covered, the root should be chipped out and a sealing run used as shown in Fig. 2.

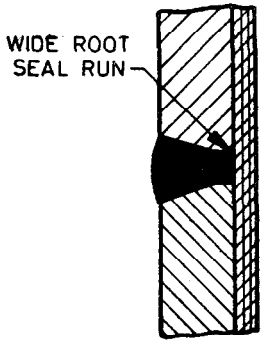

FIG. 2 SEALING RUN IN A WELDED BUTT JOINT

4.2.2.2 Wherever possible, corner joints (*see* Fig. 3A) shall be replaced by butt-welded flanged plates, as shown in Fig. 3B.

4.2.3 Pads should be avoided wherever possible, but are sometimes necessary in place of small bore branches to prevent damage during handling and erection. Fixing holes in pads shall not penetrate the shell of the vessel (*see* Fig. 4).

4.2.4 *Sectional Tanks* — Mating flanges of sectional tanks should be square and plumb, and sections shall be made strong enough to avoid distortion when bolted together. Normally, soft gaskets should be interposed between lined flanges.

*Code of procedure for manual metal arc welding of mild steel.

†Code of practice for oxy-acetylene welding for structural work in mild steel (*revised*).

‡Code for unfired pressure vessels.

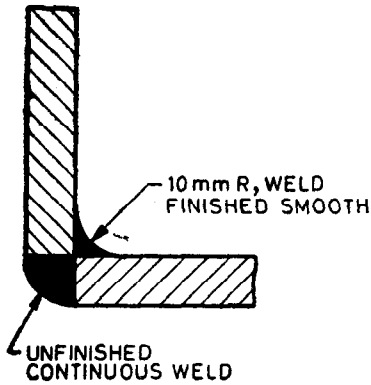

FIG. 3A A TYPICAL CORNER JOINT ALL WELDS TO BE FINISHED ROUND AND SMOOTH

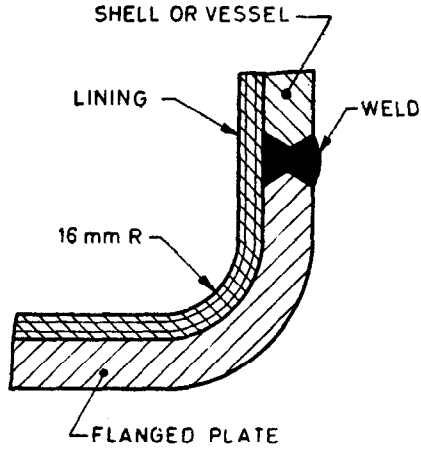

FIG. 3B BUTT-WELDED FLANGED PLATE

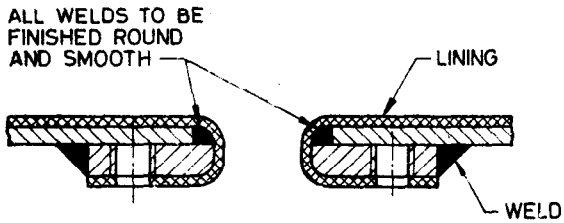

FIG. 4 OUTLET PADS

4.3 Mild Steel Pipes and Fittings — Phenolic resin linings can be applied for pipe work. The minimum size that could be satisfactorily be lined is 20 mm. But because of the special constructions the lining of pipe work should be discussed with the lining contractor.

4.4 Cast Iron Vessels — Cast iron presents difficulty in lining due to porosity, mould marks, and the effect of grain size in the casting. The factors increase the possibility of air inclusion.

4.4.1 Castings shall be of close grained iron and shall be substantially free from cavities and porosity. If any of these defects appear after casting they shall be left untreated. The remedying of any defects after shot-blasting should be agreed between supplier and the contractor. All surfaces shall be free from fins, sharp projections, etc.

4.4.2 In order to reduce the possibility of surface blowholes forming, it is preferable that the face to be covered is the lower one when the casting is made.

4.4.3 When very large, heavy or complex castings are to be lined, it is essential that the advice of the phenolic resin lining contractor be sought at an early stage.

4.5 Copper, Aluminium Alloy and Stainless Steel Vessels

4.5.1 The general construction, details and principles already given for mild steel vessels (*see* **4.2**) apply to vessels constructed of copper or aluminium alloys. All vessels should be brazed or fusion welded; rivetted construction is not acceptable. The design should provide the maximum rigidity.

4.5.2 Full details of the alloy should be given to the lining contractor for confirmation that the lining can be satisfactorily bonded.

4.6 Concrete Vessels — The current practice with phenolic resin linings is to use only heat-cured types so that the lining of concrete vessels is not recommended.

5. DESIGN OF LININGS

5.1 Selection of Materials — The selection of the phenolic resin lining should be based on the following information. When a contractor is to apply the lining full details on the duties of the vessel involved should be submitted to him.

a) *Nature of the Contents of the Vessel* — Full analysis of the contents of the vessel should be given, including constituents present in trace quantities;

b) *Temperature*
   1) Normal operating temperatures,
   2) Maximum and minimum temperatures, and
   3) Cycle of temperature variation;

c) *Degree of Vacuum or Pressure*
   1) Normal operating pressure,
   2) Maximum and minimum pressures, and
   3) Cycle of pressure variation;

d) *Cycle of Operations* — Whether batch or continuous process;

e) *Abrasion and Erosion* — Details of the amount, particle size and physical characteristics of the suspended matter, together with rates of flow should be stated; and

f) *Mechanical Damage* — The contractor should be informed of any expected difficulties involved in the handling and final siting of the equipment, of any vibration of the equipment and the possibility of any mechanical damage.

5.2 Quality of Lining — When the lining is to be applied by a contractor, the lining materials to be used shall be agreed between him and the purchaser. The contractor should be prepared to state that it will satisfy the chemical and physical conditions met with any services. The contractor should be prepared to supply samples with the lining materials or panels to which this has been applied for future reference in case of disputes. He should not change the composition in any way except by agreement with the purchaser.

5.3 Thickness of Lining

5.3.1 For corrosive conditions the dry film thickness should not be less than 0·2 mm. With lining thickness exceeding 0·3 mm, there may be a tendency to crack.

5.3.2 There will, however, be applications, such as the protection of the contents of a vessel from contamination by dissolved metal and the prevention of deposition of solids on the surface, when the thickness of lining required may be less. The use of linings on non-ferrous metal vessels generally comes into this category though, of course, each duty depends on the special circumstances involved. In any case the minimum thickness of dry film for these applications should be 0·15 mm.

6. METHODS OF LINING

6.1 Steel Vessels

6.1.1 The application of a lining over rust, scale, dirt or grease invariably leads to bad results and the importance of thorough surface preparation of the steel cannot be over-emphasized.

6.1.2 The surface shall be carefully grit blasted after degreasing. The abrasive used should be sufficiently fine, generally not coarser than 500 μm to prevent the formation of a rough surface. Traces of blast products and abrasives should be removed particularly from pockets and corners. The cleaned metal should have a uniform 'white' metal finish. It should be covered with the first coat of lining material as soon as possible, and in any case not more than four hours, after cleaning and before any visible rusting occurs.

6.1.3 To avoid condensation of moisture, the surface to which a lining is to be applied should have a temperature of at least 5°C above the dew point of the surrounding air before application of each coat.

6.1.4 It is recommended that the coats be applied by brush, especially the first coat, as brushing facilitates bringing the lining material into close contact with the surface.

Although recommendations have been made that the first coat should be applied by brush normally all the coats are applied by spray. To achieve a satisfactory protection several coats are necessary in order to achieve the thickness stipulated in **5.3**. At least four coats, usually more, are required, the first coat or coats of which are primer coats. Each coat is allowed to air dry before application of the next coat, frequently an intermediate stoving is used but this should be at a lower temperature than the final stoving to ensure good adhesion between coats.

6.2 Cast Iron Vessels

6.2.1 Because of the inherent porosity of cast iron, stoved linings are not usually very satisfactory. Best results are obtained with fine grain cast iron surfaces and special techniques, such as vacuum impregnation.

6.3 Other Metal Vessels

6.3.1 For stainless steel, copper, aluminium and their alloys the surface shall be roughened by grit blasting. The grit blasting shall never be done with abrasives containing iron or steel, since this may result in staining or corrosion of the metal surface under the lining due to iron and steel particles becoming embedded in the non-ferrous metal surfaces. It is recommended that separate blasting grits be kept for different metals to prevent contamination.

7. ACCEPTANCE TESTS

7.1 Test for Completeness of Cure

7.1.1 The hardening of a phenolic resin lining can be checked by determining the resistance of the film to methyl isobutyl ketone. When methyl isobutyl ketone is not available acetone may be used as a substitute.

This test may be carried out by laying a rag soaked in the solvent on the lining for three minutes, after which it should show no signs of softening. This may be checked by scratching with a finger nail. Any apparent softening indicates that the lining is not fully cured and further curing is required.

7.2 Visual Inspection

7.2.1 Bubbles, flaws or other imperfections in the lining indicate points of potential failure in service.

7.3 Thickness Tests

7.3.1 A number of commercial instruments are available for measuring the thickness of the lining to ensure compliance with the values given in **5.3**. It is desirable that the method of measurement is agreed between the user and the supplier.

7.4 Electrical Tests

7.4.1 The high frequency spark tested, which is usually used for testing the thick linings dealt with in other parts of the code, should not be used for the thin linings dealt with in this part. The voltage required to produce a clearly visible spark is difficult to control and thin linings are likely to be punctured as a result of such testing.

7.4.2 A high-voltage direct current test should, therefore, be used. The probe is moved systematically over the surface to be tested, which should be clean and dry. Any pinhole or crack will permit current to flow, and this is visible as an electric spark. There is no danger of puncturing the lining when the correct voltage required is adhered to, provided the probe is not kept at the same place for a long time. The voltage required depends on the thickness of the lining to be tested and should be determined by trial on coated test plates. The lining thickness on the test plate should be the minimum required on the equipment to be tested and the breakdown voltage determined on this plate. The voltage should then be reduced to a value of 75 percent of the breakdown voltage. If at this comparatively low voltage the spark at a pinhole is difficult to see, the instrument should be fitted with a neon light indicator. High-voltage test sets should have a high internal resistance or other means of limiting the current to a safe value. This type of electrical test is not suitable where conductive pigments have been used.

7.4.3 *Resistance or Wet Test* — In this test one terminal of a 12 volt dc supply is connected to the outer shell of the lined vessel and the other is joined, via a milliammeter, to a cotton wool swab or sponge saturated with a dilute (2 percent) aqueous solution of ammonium hydroxide. The swab is moved slowly over the whole surface of the lining so that any defect is indicated by a reading on the milliammeter.

7.4.4 Any vessel showing a large number of points of failure should be rejected. Where failure occurs over only a small area, local patching may be allowed. In very slightly corrossive conditions a few scattered imperfections may be tolerated, but for more stringent duties the electrical test should reveal no breakdown.

8. ROUTINE INSPECTION AND REPAIRS

8.1 Routine Inspection

8.1.1 To ensure the satisfactory operation of lined plant and equipment, it is necessary to carry out periodic inspection to make sure that the lining

is sound. The frequency of these inspections will depend on the nature of the materials being handled. During these inspections damage to the lining shall be avoided by suitably covering footwear, ladders, etc. Visual inspection, thickness tests and electrical tests should be done in accordance with **7.2**, **7.3** and **7.4**.

8.2 Repairs

8.2.1 Damaged phenolic resin linings may be successfully repaired, but skilled labour is required and this work is normally carried out by the lining contractor. Repairs can only be made to small areas and the repair technique consists essentially of cleaning, roughening and coating the area concerned, followed by localized heating, for example by means of infra-red heaters.

APPENDIX A

(*Clause* 0.5)

EXCHANGE OF INFORMATION

A-1. Early consultation and exchange of information should be arranged between all parties concerned with the design, use, manufacture and erection of the vessels and equipment to be lined, and the lining contractor. Adequate and accurate scale drawings should be available to all parties concerned. Consultations may be desirable on:

a) site conditions which may affect this particular work and the availability of services for site lining;

b) safety measures to be taken during lining;

c) construction of equipment to be lined, location of welds, joints and supports and the finish of the surface to be lined;

d) nature and concentration of media for which vessel or equipment is required;

e) operating temperatures and pressures;

f) other factors influencing material stress, for example, expansion, vibration, or impact of contents on lining;

g) presence of abrasives in contents, and potential local erosion by fluids;

h) internal or external installation and means of access, lifting facilities;

j) where necessary, the nature of the surface finish required of the lining;

k) service life expected; and

m) method of heating and cooling.

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